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DATE: Monday, September 11, 2006 **Purge Queries** Printable Copy
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L21: Entry 4 of 5 File: USPT Oct 16, 1990

US-PAT-NO: 4964125
DOCUMENT-IDENTIFIER: US 4964125 A

TITLE: Method and apparatus for diagnosing faults

DATE-ISSUED: October 16, 1990

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Kim; Sachol E.	Yorba Linda	CA		

US-CL-CURRENT: 714/26; 706/49, 706/911, 706/916

ABSTRACT:

The present invention is directed to an expert system for diagnosing faults. The system comprises a knowledge base containing information regarding a conceptual model of the equipment under diagnosis. The system also comprises an inference engine for generating a set of symptom diagnostic rules from the information contained within the knowledge base in conjunction with user-generated inputs.

35 Claims, 26 Drawing figures
Exemplary Claim Number: 1
Number of Drawing Sheets: 18

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L21: Entry 4 of 5 File: USPT Oct 16, 1990

DOCUMENT-IDENTIFIER: US 4964125 A
TITLE: Method and apparatus for diagnosing faults

Application Filing Date (1):
19880819

Assignee Name (1):
Hughes Aircraft Company

Assignee Group (1):
Hughes Aircraft Company Los Angeles CA 02

Detailed Description Text (8):
Based on the information retrieved by the blackboarder routine 30, the inference engine 28 attempts to isolate the fault. If the fault is isolated, the inference engine 28 indicates to the user that the fault has been isolated and the session is terminated. The user may then use the information obtained from the system 24 to correct the fault in the equipment. If the inference engine 28 is not able to diagnose the fault, it then determines which test should be performed on the equipment and asks the user to perform the test.

Detailed Description Text (9):
If the inference engine 28 does not isolate the fault, it may encounter an infinite loop if it repeatedly examines the same knowledge. The possibility that an infinite loop may occur is minimized, however, since approximately half the fault domain of the equipment is eliminated each time the inference engine 28 conducts a new test. On the other hand, if the inference engine 28 encounters a previously tested location, the system 24 terminates its fault diagnosis, and alerts the user that more information about a certain area of the equipment 24 is needed by generating an ignorance message.

Detailed Description Text (54):
The knowledge base 32 is then examined to determine whether the analytical truth corresponds to reality. This is done by determining the synthetic truth of the knowledge base 32. The synthetic truth is established to the extent that a set of selected faults inserted into the equipment are correctly isolated. For those selected faults which are not correctly fault isolated, a revision of the knowledge base 32 is performed.

Detailed Description Text (55):
The third goodness criteria against which the knowledge base 32 is tested is completeness. Completeness means that the knowledge base 32 has a complete knowledge about the manner in which the electronic equipment 32 is designed to work. The degree of completeness is determined by the frequency of ignorance or inability of the system 24 to isolate a fault. After the completeness of the knowledge base 32 has reached a level acceptable to the user (for example, 99 fault isolations out of 100 attempts), the knowledge base 32 may be used in conjunction with the inference engine 28 to perform diagnosis.

Detailed Description Text (64):

The fourth logical component is the cell internal control heuristic ("CICH") which acts on the knowledge cell that the blackboarder-knowledge cell routine has constructed. The cell internal control heuristic isolates a fault in the knowledge cell or decomposes the knowledge cell if the cell is a composite. The cell internal control heuristic then calls the global control heuristic to restart a separate cyber transition sequence or cause the diagnosis to exit with a cell knowledge deficiency statement.

Detailed Description Text (67):
A block diagram of the inference engine 28 is shown in FIG. 13. The inference engine 28 comprises a find fault cell routine ("FF-C") 102 and a find fault routine ("FF") 104. The find fault cell routine 102 is used to generate the cyber transition sequence which terminates with a cyber having the name of a fault cell. The find fault routine 104 is then used to isolate the fault within the fault cell. During operation, if the find fault cell routine 102 locates a fault cell, the processing flows along path "a" to the find fault routine 104 with the value of task i equal to zero. When the task i equals zero, the find fault routine 104 is instructed to check for each possible fault starting from the initial task (i.e., the find fault routine 104 will examine the downlinks, uplinks, enablement conditions and so forth to determine whether the equipment is exhibiting these particular faults). If it is determined that the knowledge cell under consideration is in fact a composite knowledge cell, the find fault cell routine 102 is instructed to level down to another taxonomical piece. This is done by the generation of a TT=0 output by the find fault routine 104 which is delivered to the find fault cell routine 102 along path "d". If it is determined that the fault of the current knowledge cell is due to another cyber, the find fault cell routine 102 is instructed to generate another cyber transition sequence beginning from another knowledge cell. This is done by generation of a TT=0 output by the find fault routine 104 which is delivered to the find fault cell routine 102 along path "e".

Detailed Description Text (75):
After executing step 144, or if at step 142 task i does not equal zero, step 146 is executed which calls the cell internal control heuristic. As described below, the cell internal control heuristic is used for isolating a fault in the fault cell. In executing step 146, the find fault routine 104 passes to the cell internal heuristic the name of the taxonomical piece in which the knowledge cell is located, the name of the fault cell, and the value of task i.

Detailed Description Text (76):
If the cell internal control heuristic succeeds in isolating the fault within the fault cell, there is no need to construct another cyber transition sequence. Accordingly, the inference engine 28 then calls the find fault cell routine 102 at steps 148 and 150 of the find fault routine 104. In this case, the find fault cell routine 102 will either decompose the current fault cell if it is a composite cell by leveling down (i.e., TT=0), or will terminate diagnosis with an "F-cell ignorance" signal at step 112. If the cell internal control heuristic does not fault isolate, and indicates that a new cyber transition sequence must be generated, the find fault cell routine 102 is called at step 152. When this occurs, the value of TT is set equal to zero to indicate that an excursion departure will occur in indicating that the fault of the knowledge is due to a fault in another cyber.

Detailed Description Text (98):
After executing step 322, or after modifying the intrinsic task sequence at step 230, or if at step 308 it is determined that the task i does not equal 0, step 324 is executed, which brings in the next task as task i. After executing step 324, it is determined at step 326 whether there are any more tasks to consider. If there are no more tasks to consider, step 328 determines whether the knowledge cell is simple. If it is, step 330 is executed which indicates that the fault appears in the particular physical device and that fault isolation has occurred. If the cell

is not simple, step 332 is executed which terminates diagnosis with an ignorance condition indicating that the composite cell has not been found to contain a fault.

Detailed Description Text (101):
If at step 334 the task i does not represent an uplink check, step 342 determines whether the task i represents an enablement conditions check. If task i represents an enablement conditions check, the enablement conditions are probed at step 344. After the enablement conditions are probed, it is determined at step 346 whether all the enablement conditions are normal. If all the enablement conditions are normal, step 324 is executed. If at step 346 it is determined that not all the enablement conditions probed are normal, step 348 is executed which indicates that an enablement conditions fault has occurred and that the fault has been isolated.

CLAIMS:

1. An expert system for diagnosing faults in equipment, said system including a computer having a memory for storing diagnostic routines and a user interface that permits communication between the expert system and an operator, said system comprising:

a knowledge base coupled to the computer for storing data that is defined by a plurality of files that characterize the physical, functional and operational relationships of the components and between components of the equipment and information concerning selected operating conditions of the equipment, said files containing data indicative of the following attributes of the equipment: (1) the function of each component, (2) a wire list indicating outputs and interconnection of a component to other components of the equipment, (3) a level jump condition indicator which indicates whether a component may be decomposed into a plurality of other components, (4) a test message representing a stimulus applied to generate outputs that indicates whether a component is faulty, and (5) a listing of normal operating state values for a component indicating when that component is not faulty when the stimulus is applied thereto; and

an inference engine that is storable in said memory that interfaces with the knowledge base and the operator by way of the user interface and which comprises recursive diagnostic routines that operate on the data contained in the knowledge base to generate symptom diagnostic rules in response to operator entered symptoms which are indicative of the faults present in the equipment.

9. The expert system of claim 8, wherein each of said knowledge cells is of a type selected from the group consisting of a blank cell, a regular cell, a simple cell, a composite cell, a logical cell and a boundary cell.

19. The expert system of claim 16, wherein said inference engine further comprises means for isolating a faulty knowledge cell from the information contained on said blackboard.

20. The expert system of claim 19, wherein said means for isolating a faulty knowledge cell is operable to decompose said knowledge cell when said knowledge cell is composed of other knowledge cells.

24. A process for operating a digital computer to enable a user to correct a fault in electronic equipment having a plurality of components, said computer having a memory for storing a knowledge base having a plurality of knowledge cells representing a functional portion of said electronic equipment and comprising a set of normal operating state values associated with said knowledge cells, and means for indicating whether said knowledge cells are decomposable into other knowledge cells, said knowledge cells being grouped into a plurality of taxonomical pieces that form a determinant of said electronic equipment, said process comprising the

steps of:

(a) locating a fault in said knowledge cells in said determinant by comparing said normal operating state values of said knowledge cells with test data derived from applying selected inputs to said electronic equipment to generate outputs therefrom;

(b) indicating an ignorance condition and terminating said process if said knowledge cell determined to be faulty has been previously located;

(c) attempting to isolate said fault in said knowledge cell which has been determined to be faulty;

(d) indicating an ignorance condition and terminating said process if said fault is not isolated after repeatedly attempting to isolate said fault a predetermined number of times;

(e) indicating the existence of a fault isolation condition and terminating said process if said fault is isolated; and

(f) repeating steps (a) through (e);

whereby the fault in said electronic equipment is isolated by said digital computer to thereby permit the user to correct the fault in said electronic equipment.

25. The process of claim 24, wherein said knowledge cells comprise files containing data indicative of the following attributes: (1) the function of each component of the equipment, (2) a wire list indicating outputs and interconnection of a component of the equipment to other components thereof, (3) a level jump condition indicator which indicates whether a component of the equipment may be decomposed into a plurality of other components, and (4) a test message representing a stimulus applied to generate outputs that indicates whether a component is faulty.

32. The process of claim 31, wherein said step of attempting to isolate said fault in said knowledge cell comprises the step of accessing said knowledge base to construct said knowledge cell on said blackboard.

34. The process of claim 32, wherein said step of attempting to isolate said fault in said knowledge cell comprises the step of decomposing said knowledge cell when said knowledge cell is composed of other knowledge cells.

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